Percent Reaction (%)	Equilibrium Constant, K_a (mol/L)	Acid		Conjugate Base	
		Name	Formula	Formula	Name
100	very large	perchloric acid	$HClO_{4(aq)}$	$ClO_4^-{}_{(aq)}$	perchlorate ion
100	3.2×10^9	hydroiodic acid	$HI_{(aq)}$	$I^-{}_{(aq)}$	iodide ion
100	1.0×10^9	hydrobromic acid	$HBr_{(aq)}$	$Br^-{}_{(aq)}$	bromide ion
100	1.3×10^6	hydrochloric acid	$HCl_{(aq)}$	$Cl^-{}_{(aq)}$	chloride ion
100	1.0×10^3	sulfuric acid	$H_2SO_{4(aq)}$	$HSO_4^-{}_{(aq)}$	hydrogen sulfate ion
100	2.4×10^1	nitric acid	$HNO_{3(aq)}$	$NO_3^-{}_{(aq)}$	nitrate ion
—	—	hydronium ion	$H_3O^+{}_{(aq)}$	$H_2O_{(l)}$	water
51	5.4×10^{-2}	oxalic acid	$HOOCCOOH_{(aq)}$	$HOOCCOO^-{}_{(aq)}$	hydrogen oxalate ion
30	1.3×10^{-2}	sulfurous acid (SO_2 + H_2O)	$H_2SO_{3(aq)}$	$HSO_3^-{}_{(aq)}$	hydrogen sulfite ion
27	1.0×10^{-2}	hydrogen sulfate ion	$HSO_4^-{}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$	sulfate ion
23	7.1×10^{-3}	phosphoric acid	$H_3PO_{4(aq)}$	$H_2PO_4^-{}_{(aq)}$	dihydrogen phosphate ion
8.1	7.2×10^{-4}	nitrous acid	$HNO_{2(aq)}$	$NO_2^-{}_{(aq)}$	nitrite ion
7.8	6.6×10^{-4}	hydrofluoric acid	$HF_{(aq)}$	$F^-{}_{(aq)}$	fluoride ion
4.2	1.8×10^{-4}	methanoic acid	$HCOOH_{(aq)}$	$HCOO^-{}_{(aq)}$	methanoate ion
—	$\sim 10^{-4}$	methyl orange	$HMo_{(aq)}$	$Mo^-{}_{(aq)}$	methyl orange ion
—	6.3×10^{-5}	benzoic acid	$C_6H_5COOH_{(aq)}$	$C_6H_5COO^-{}_{(aq)}$	benzoate ion
2.3	5.4×10^{-5}	hydrogen oxalate ion	$HOOCCOO^-{}_{(aq)}$	$OOCCOO^{2-}{}_{(aq)}$	oxalate ion
1.3	1.8×10^{-5}	ethanoic (acetic) acid	$CH_3COOH_{(aq)}$	$CH_3COO^-{}_{(aq)}$	ethanoate (acetate) ion
—	4.4×10^{-7}	carbonic acid (CO_2 + H_2O)	$H_2CO_{3(aq)}$	$HCO_3^-{}_{(aq)}$	hydrogen carbonate ion
—	$\sim 10^{-7}$	bromothymol blue	$HBb_{(aq)}$	$Bb^-{}_{(aq)}$	bromothymol blue ion
0.10	1.1×10^{-7}	hydrosulfuric acid	$H_2S_{(aq)}$	$HS^-{}_{(aq)}$	hydrogen sulfide ion
0.079	6.3×10^{-8}	dihydrogen phosphate ion	$H_2PO_4^-{}_{(aq)}$	$HPO_4^{2-}{}_{(aq)}$	hydrogen phosphate ion
0.079	6.2×10^{-8}	hydrogen sulfite ion	$HSO_3^-{}_{(aq)}$	$SO_3^{2-}{}_{(aq)}$	sulfite ion
0.054	2.9×10^{-8}	hypochlorous acid	$HClO_{(aq)}$	$ClO^-{}_{(aq)}$	hypochlorite ion
—	$\sim 10^{-10}$	phenolphthalein	$HPh_{(aq)}$	$Ph^-{}_{(aq)}$	phenolphthalein ion
0.0078	6.2×10^{-10}	hydrocyanic acid	$HCN_{(aq)}$	$CN^-{}_{(aq)}$	cyanide ion
0.0076	5.8×10^{-10}	ammonium ion	$NH_4^+{}_{(aq)}$	$NH_{3(aq)}$	ammonia
0.0076	5.8×10^{-10}	boric acid	$H_3BO_{3(aq)}$	$H_2BO_3^-{}_{(aq)}$	dihydrogen borate ion
0.0022	4.7×10^{-11}	hydrogen carbonate ion	$HCO_3^-{}_{(aq)}$	$CO_3^{2-}{}_{(aq)}$	carbonate ion
0.00020	4.2×10^{-13}	hydrogen phosphate ion	$HPO_4^{2-}{}_{(aq)}$	$PO_4^{3-}{}_{(aq)}$	phosphate ion
0.00013	1.8×10^{-13}	dihydrogen borate ion	$H_2BO_3^-{}_{(aq)}$	$HBO_3^{2-}{}_{(aq)}$	hydrogen borate ion
0.00011	1.3×10^{-13}	hydrogen sulfide ion	$HS^-{}_{(aq)}$	$S^{2-}{}_{(aq)}$	sulfide ion
0.000040	1.6×10^{-14}	hydrogen borate ion	$HBO_3^{2-}{}_{(aq)}$	$BO_3^{3-}{}_{(aq)}$	borate ion
—	—	water	$H_2O_{(l)}$	$OH^-{}_{(aq)}$	hydroxide ion

- The percent reaction of acids with water is for 0.10 mol/L solutions and is only valid for concentrations close to 0.10 mol/L. All measurements of acid strengths were made at SATP. No percent reaction is given for benzoic acid or carbonic acid because these acids have molar solubilities less than 0.10 mol/L at SATP. No percent reaction is given for indicators because indicators are generally used at concentrations lower than 0.10 mol/L.

- Values in this table are taken from *Lange's Handbook of Chemistry*, 13th Edition.

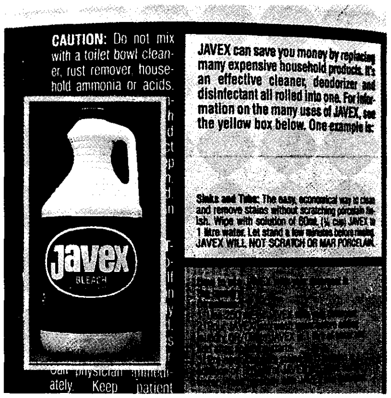

Figure 15.15
Bottles of household bleach display a warning against mixing the bleach (aqueous sodium hypochlorite) with acids. Does your prediction of the reaction between vinegar and hypochlorite ions provide any clues about the reason for the warning?

2. Identify all possible acids and bases, using the Brønsted-Lowry definitions.
3. Identify the strongest acid and the strongest base present, using the table of acids and bases (Appendix F, page 611).
4. Transfer one proton from the acid to the base and predict the conjugate base and the conjugate acid as the products.
5. Predict the position of the equilibrium, using the generalization developed on page 531 and the table of acids and bases (Appendix F, page 611).

Exercise

Use the five-step method to make predictions for the predominant reactions in the following chemical systems.

16. Hydrofluoric acid and an aqueous solution of sodium sulfate are mixed to test the five-step method of predicting acid-base reactions.
17. Strong acids, such as perchloric acid, have been shown to react quantitatively with strong bases, such as sodium hydroxide.
18. Predict the acid-base reaction of bleach with vinegar (Figure 15.15).
19. Methanoic acid is added to an aqueous solution of sodium hydrogen sulfide.
20. A student mixes solutions of ammonium chloride and sodium nitrite in a chemistry laboratory.
21. Empirical work has shown that nitric acid reacts quantitatively with a sodium acetate solution.
22. A consumer attempts to neutralize an aqueous sodium hydrogen sulfate cleaner with a solution of lye. (See Appendix G, page 612, if you do not remember what lye is.)
23. Can ammonium nitrate fertilizer, added to water, be used to neutralize a muriatic acid (hydrochloric acid) spill?

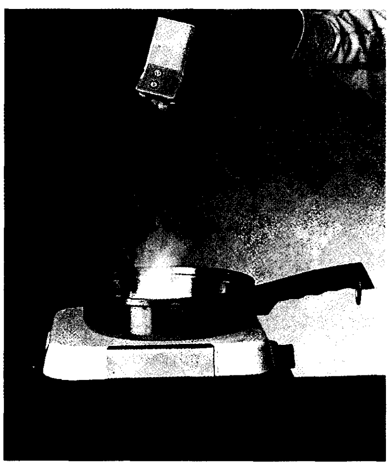

Figure 15.16
The versatility of baking soda is demonstrated by its use in extinguishing fires, in baking biscuits, and in neutralizing excess stomach acid. It is also used as a medium for local anesthetics — apparently, baking soda reduces stinging sensations by neutralizing the acidity of the anesthetic, with the result that the speed and efficiency of the anesthetic are improved. The broad range of uses for baking soda results, in part, from its amphiprotic character.

Lab Exercise 15D Testing the Five-Step Method

Complete the Prediction, Analysis, and Evaluation of the investigation report.

Problem

What are the products and position of the equilibrium for sodium hydrogen carbonate (Figure 15.16) with stomach acid, vinegar, household ammonia, and lye, respectively?

Experimental Design

Each of the chemicals is prepared as a solution with a concentration between 0.1 mol/L and 1.0 mol/L. Evidence is gathered to test the predicted products and the position of the equilibrium .